DIET QUALITY, CHANGE IN DIET QUALITY AND RISK OF INCIDENT CARDIOVASCULAR DISEASE AND DIABETES: THE ATHEROSCLEROSIS RISK IN COMMUNITIES (ARIC) STUDY

by

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ABSTRACT

Background: Dietary intake is a modifiable risk factor for cardiovascular disease (CVD) and diabetes. There is limited evidence on diet quality and diet quality change in the general population and their potential prospective associations with cardiovascular disease and diabetes.

Objective: To assess the association between diet quality and diet quality change with subsequent risk for incident CVD and diabetes in the Atherosclerosis Risk in Communities (ARIC) Study.

Design: We included 11,079 ARIC study participants who reported usual dietary intake via food frequency questionnaire at visit 1 (1987-1989) and who had not developed CVD, diabetes, or cancer at baseline. Diet quality was assessed using the Healthy Eating Index (HEI)-2015 and the Alternative HEI (AHEI)-2010 scores. We used Cox regression models with multiple adjustment to estimate hazard ratios (HR) and 95% confidence intervals (CI) for incident CVD and diabetes. Associations between change in diet quality scores from visit 1 to visit 3 (6 years) and incident CVD and diabetes were also examined.

Results: Overall, there were 3,138 participants who developed CVD (median follow-up of 26 years) and 3,542 developed diabetes after visit 1 (median follow-up of 22 years). Higher diet score at the initial visit was associated with a significantly lower risk of CVD: HR, 0.90 (95% CI, 0.86 to 0.95) per 10% increase in initial diet score in HEI-2015 and HR, 0.96 (95% CI, 0.93 to 0.99) per 10% increase in AHEI-2010. We did not observe a significant association between initial diet score and incident diabetes (p-values >0.05). There were no significant associations between change in diet score and CVD or diabetes risk in the overall study population.

Conclusions: Higher diet quality assessed using HEI-2015 and AHEI-2010 was strongly associated with a lower CVD risk but not diabetes risk within a middle-aged, community-based U.S. population. Adherence to current dietary guidelines could potentially confer benefits for CVD prevention.

Keywords: Diet quality; Change; Cardiovascular disease; Diabetes; HEI-2015; AHEI-2010

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PREFACE

Unhealthy diet is an important modifiable risk factors for chronic diseases. This study focused on diet quality, cardiovascular disease, and diabetes risk among community-based U.S. population. We also examined the effect of diet quality change on the development of incident cardiovascular disease and diabetes. Using the latest version of Healthy Eating Index (HEI) and Alternative HEI to measure diet quality, I calculated the diet quality scores, described the characteristics of diet quality, and conducted Cox proportional hazard regression to explore the association between diet quality and cardiovascular disease/diabetes risk to provide scientific evidence for healthy diet prevention among the general population.

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INTRODUCTION

Cardiovascular disease (CVD) remains the primary leading cause of death and a major cause of morbidity in the United States and globally (1–3). An estimated 92.1 million US adults have at least one type of CVD (4). As a potent risk factor for CVD, diabetes mellitus is one of the fastest growing diseases (5). Over the past two decades, the prevalence of diabetes has increased substantially and 21 million adults are affected in the United States (6). Dietary intake is an important modifiable risk factor for chronic disease, including both CVD and diabetes mellitus (7). Evidence from both observational studies and clinical trials has accumulated over the past two decades, highlighting the importance of individual nutrients, foods, and dietary patterns for CVD and diabetes prevention and management (8–12).

The 2015-2020 Dietary Guidelines for Americans outline recommendations for dietary intake for the U.S. population. As measures of diet quality, the Health Eating Index (HEI) assesses adherence to the dietary guidelines and the Alternative Healthy Eating Index (AHEI) assesses dietary components that have been associated with a lower risk of chronic diseases (12). Higher levels of diet quality, assessed using the 2010 version of the HEI and the AHEI, have been documented to be associated with a lower risk of diabetes, cardiovascular disease, and mortality (12,13). However, the association between diets that are consistent with the most recent (2015-2020) Dietary Guidelines and major chronic disease among community-based U.S. population has not been evaluated.

Previous research has identified an improvement in dietary intake in the U.S. over the past few decades, with an increased consumption of whole grains, fruits, and vegetables, but overall diet quality remains far from optimal (14–16). There is limited evidence on individual-level change in diet quality and subsequent health outcomes. In studies of predominantly Caucasian nurses and other health professionals in the U.S., deterioration of diet quality was associated with an elevated risk of CVD and diabetes, and improvement in diet quality was associated with a lower risk of CVD and diabetes (17,18). It is not known whether these findings can be extended to other segments of the U.S. population.

The objective of the present study was to assess the prospective association between diet quality as well as 6-year change in diet quality and subsequent risk for incident CVD and diabetes in a community-based population of black and white adults.

METHODS

Study Population and Design

The Atherosclerosis Risk in Communities (ARIC) Study is a community-based, prospective cohort study, which recruited 15,792 participants aged 45 to 64 years at baseline from four U.S. communities (Washington County, Maryland; Forsyth County, North Carolina; Jackson, Mississippi; and Minneapolis, Minnesota) (19). The first study visit occurred in 1987 to 1989. Follow-up examination visits were conducted in 1990 to 1992 (visit 2), 1993 to 1995 (visit 3), 1996 to 1998 (visit 4), and 2011 to 2013 (visit 5). Annual follow-up telephone calls were also conducted from 1987.

In this prospective analysis of the ARIC Study, we examined the association between initial diet quality (at visit 1) as well as diet quality change from visit 1 to visit 3 and incident CVD and incident diabetes. Participants who developed diabetes, CVD, or cancer at baseline were excluded (n = 3,738). We also excluded participants with implausible energy intake (<600 kcal or >4200 kcal per day for men and <500 kcal or >3600 kcal per day for women) (n = 256), missing dietary data (n = 71), missing covariates (age, race, sex, physical activity, smoking status, education, BMI, eGFR level, hypertension, and hypercholesteremia status) (n = 648). A total of 11,079 participants were included in the analysis of diet quality (visit 1) and incident CVD and diabetes.

For the analysis of change in diet quality, incident CVD, and incident diabetes, we excluded participants with prevalent diabetes, CVD, or cancer prior to visit 3 (n = 4,228) from the 12,887 participants who attended visit 3. We also excluded participants with implausible energy intake (n = 403), missing dietary data (n = 117), missing covariates (n = 515) measured at visit 3, and missing follow-up time (n = 21). A total of 7,603 participants were included in the analysis of change in diet quality, incident CVD, and incident diabetes. The Institutional Review Boards at all participating study centers reviewed and approved the study.

Dietary Intake Assessment

Dietary intake was assessed at visit 1 and visit 3 using a validated semi-quantitative 66-item food frequency questionnaires (FFQ), which was modified from the Willett FFQ (20–22). Participants were asked to report the average frequency of each food item they consumed of a particular portion size in the preceding year. Nutrient intake was calculated by multiplying self-reported frequency of consumption and portion size by the nutritional content of each food item using U.S. Department of Agriculture data sources (23).

The Healthy Eating Index (HEI)-2015 and the Alternative Healthy Eating Index (AHEI)-2010 were used to represent diet quality and adherence to healthy eating for chronic disease prevention. HEI-2015 is the latest iteration of the index and was designed to assess adherence to the 2015-2020 DGAs. It consists of 13 components that sum to a total maximum score of 100 points: total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, fatty acids, refined grains, sodium, added sugars, and saturated fats (24). In the AHEI-2010, which was created to reflect foods and nutrients that have been consistently associated with a lower risk of chronic diseases, there are 11 food components that sum to a total maximum score of 110: vegetables, fruits, whole grains, nuts and legumes, long-chain n-3 fatty acids, polyunsaturated fatty acids (excluding long-chain n-3 fatty acids), red/processed meat, sugar-sweetened beverages and fruit juice, trans fat, sodium, and alcohol consumption (12,18).

We categorized diet quality using HEI-2015 and AHEI-2010 scores at visit 1 as quintiles. We categorized change in diet quality scores over a six-year period from visit 1 to visit 3 as follows: large decrease in the diet quality score (<-10%), small to moderate decrease (≥-10% to <-3%), no change or stable (-3% to +3%), small to moderate decrease (>+3% to ≤+10%), and large decrease (>+10%). We also expressed change in diet quality using 9 categories representing consistently low diet quality, consistently moderate diet quality, consistently high diet quality, and inconsistent diet quality scores (low to moderate; low to high; moderate to high; moderate to low; high to moderate; high to low).

Ascertainment of Incident CVD

We defined incident CVD as the first occurrence of any of the following: died or hospitalized with an ICD-9 code for heart failure (HF); coronary heart disease (CHD) (including hospitalized myocardial infarction, fatal CHD or cardiac procedure); stroke. Events were identified through cohort annual telephone follow-up, active community surveillance, and linkage with state vital statistics databases for fetal CVD events (25). Outcomes were documented from baseline, which was visit 1 for the initial diet quality exposure, and was visit 3 for the change in diet quality exposure, through December 31, 2016 (26). Incident HF, CHD, and stroke were also investigated separately as secondary outcomes.

Ascertainment of Incident Diabetes

Incident diabetes in this study was ascertained from visit 1 for the initial diet quality exposure and from visit 3 for the change in diet quality exposure through December 31, 2016. Incident diabetes was defined as self-report of a physician diagnosis, current glucose lowering medication use as determined during ARIC visits and subsequent annual follow-up phone interviews, or elevated blood glucose levels (fasting glucose $\geq$ 126 mg/dL or non-fasting glucose $\geq$ 200 mg/dL) measured using the hexokinase method during ARIC visits (27,28).

Measurement of Covariates

Information about age, sex, race, education level, physical activity, smoking status, family history (any parent) of diabetes, and family history (any parent) of coronary heart disease or stroke was collected via structured questionnaires administered to participants by trained interviewers at study visits. Self-report of physical activity type, duration, frequency, and intensity was assessed using the Baecke questionnaire and leisure-time (sport) physical activity was expressed as a score ranging from 1 to 5, with 5 being the most active (29). Self-reported family history of diseases including diabetes, CHD, or stroke was ascertained if at least one of the participant's parents had these diseases.

Body mass index (BMI) was calculated as weight (in kilograms) divided by height (in meters) squared using measurements taken during the study visits. Blood pressure was measured via a standardized protocol, and the mean of the second and third of three readings was used. Hypertension was defined as systolic blood pressure ≥ 140 mmHg, diastolic blood pressure ≥ 90 mmHg, or use of blood pressure lowering medication within the past 2 weeks. Hypercholesterolemia was defined as total cholesterol ≥ 240 mg/dL or self-reported use of cholesterol lowering medication within the past 2 weeks (30). Estimated glomerular filtration rate (eGFR) was calculated using the Chronic Kidney Disease Epidemiology (CKD-EPI) 2009 equation which incorporates serum creatinine, age, sex, and race (31).

Statistical Analysis

We used descriptive statistics to report the overall HEI-2015 and AHEI-2010 diet quality scores and specific food and nutrient components of these diet quality scores at visit 1 and visit 3. Study participant characteristics at visit 1 were compared across quintiles of diet quality at visit 1. We also reported participant characteristics at visit 3 according to categories of change in diet quality. Differences across quintiles of diet quality and categories of change in diet quality were tested using analysis of variance (ANOVA) for continuous variables and Pearson's chi-squared test for dichotomous and categorical variables.

Cox proportional hazard regression was used to estimate hazard ratios (HR) and 95% confidence intervals (CI) for the association between initial (visit 1) diet quality (HEI-2015, AHEI-2010) and incident CVD and incident diabetes, incorporating time to event. We also used Cox proportional hazard regression to estimate the association between change in diet quality and incident CVD and diabetes. Trend was tested using an ordinal variable for quintile of diet quality score in Cox regression.

Different regression models were developed to account for potential confounders. For the analyses of initial diet score as the exposure, we developed 3 models. Model 1 was adjusted for age (continuous), sex, race-center, education level (< high school, high school, > high school), family history of diabetes (yes/no), family history of CHD or stroke (yes/no), smoking status (current/former/never smoker), physical activity (quintile), and total energy intake (quintile). Model 2 was additionally adjusted for hypertension status (yes/no), hypercholesterolemia status (yes/no), and eGFR (quintile). In Model 3, we adjusted for all the covariates in Model 2 plus BMI category (<25, ≥25-<30, ≥30 kg/m^2) to incorporate the potential influence of BMI on the association between diet quality and disease risk. In addition, levels in alcohol intake were included as a covariate in models for HEI-2015, but not for AHEI-2010, since alcohol intake was a component of the AHEI-2010 score.

For the analyses of change in diet quality as the exposure, we adjusted the same covariates measured at visit 3 (visit 1 eGFR level was used because serum creatinine was not measured at visit 3), and additionally adjusted for change in smoking status (categorical), change in physical activity (quintile), change in total energy intake (quintile), and change in BMI (quintile).

To assess the robustness of our findings, we performed sensitivity analyses. We conducted subgroup analyses according to sex, race, education level, and BMI category.

All analyses were conducted using Stata version 14 (StataCorp LP, College Station, Texas). Statistical significance was assessed using a two-sided probability of alpha-level of 0.05.

RESULTS

Baseline Characteristics According to Initial Diet Quality (Visit 1)

Among the 11,079 participants in the analytic study population, the mean age at baseline was 53.7 (SD 5.7) years, 23.5% were black, and 55.9% were women. Participants with higher HEI-2015 diet quality score were more likely to be older, female, non-black, more highly educated, not current smokers, had lower alcohol intake, had a higher level of physical activity, and were more likely to have hypercholesterolemia (**Table 1**). Mean baseline weight and BMI were the lower among those who had a higher diet quality score. Similar patterns were observed across the quintiles of AHEI-2010 score.

Change in Diet Quality

There was a small, but statistically significant increase in mean diet quality scores over the six-year period for HEI-2015 [visit 1: 71.0 (SD 8.7), visit 3: 72.9 (SD 8.4); **Supplemental Table 1**] and AHEI-2010 [visit 1: 50.7 (SD 12.1), visit 3: 52.4 (11.3); **Supplemental Table 2**] (both $p<0.001$). Scores for the consumption of fruit and vegetables were significantly higher at visit 3 relative to visit 1. For HEI-2015, participants had significant improvements in diet scores for greens and beans, fatty acids, sodium, added sugars, saturated fats, and a decrease in diet component scores for total protein foods and seafood/plant proteins. For AHEI-2010, diet component scores increased over time for red/processed meat, trans fat, long-chain (n-3) fats, and scores decreased over time for PUFA, sodium, and alcohol intake.

Baseline Characteristics (Visit 3) According to Change in Diet Quality

Participants with an increase in HEI-2015 diet quality scores had lower diet quality scores at visit 1, were more likely to be younger, male, black, non-smokers, and had a higher increase in energy intake from visit 1 to visit 3 (**Supplemental Table 3**). Mean weight and BMI at visit 3 were the lower for those with stable or small increase in diet quality. The average weight and BMI increased over the six-year period, but participants with greater increase in diet scores tended to have less weight gain. Similar patterns, although less noticeable differences, were observed across the five categories of change in AHEI-2010 score.

Initial Diet Quality and Incident CVD and Diabetes

A total of 3,138 participants developed CVD and 3,542 developed incident diabetes after visit 1 during a median follow-up of 26.0 years (236,674 person-years) and

22.0 years (208,145 person-years), respectively. The overall crude CVD incidence rate was 13.3 per 1,000 person-years (95% CI, 12.8 to 13.7 per 1,000 person-years). The crude incidence rate of diabetes was 17.0 per 1,000 person-years (95% CI, 16.5 to 17.6 per 1,000 person-years).

Higher initial diet quality score was significantly associated with a 16% to 21% reduced risk of incident CVD (HEI-2015: HR for quintile 5 vs. 1, 0.79; 95% CI, 0.70 to 0.90; AHEI-2010: HR for quintile 5 vs. 1, 0.84; 95% CI, 0.74 to 0.95) in Model 3, which adjusted for age, sex, race, education, family history of diabetes, family history of CHD/stroke, smoking status, physical activity, alcohol intake (only for HEI), total energy intake, hypertension status, hypercholesterolemia status, eGFR, and BMI category (**Table 2**). There was a significant inverse trend in CVD risk across quintiles of HEI-2015 diet quality score (p-trend <0.001). Per 10% increase in HEI-2015 was associated with 10% lower risk of CVD (HR, 0.90; 95% CI, 0.86 to 0.95). Per 10% increase in AHEI-2010 was associated with 4% lower risk of CVD (HR, 0.96; 95% CI, 0.93 to 0.99). These findings were consistent for the association between HEI-2015 and incident heart failure, CHD, and stroke (**Figure 1**). There was no significant trend between higher scores for AHEI-2010 and risk of individual types of CVD. We did not observe a significant relationship between initial diet quality score (both HEI-2015 and AHEI-2010) and incident diabetes.

Diet Quality Change and Incident CVD and Diabetes

We documented 1,833 CVD cases and 2,043 diabetes cases after visit 3 during a median follow-up of 20.5 years (132,079 person-years) and 18.2 years (118,208 person-years), respectively. The crude CVD incidence rate after visit 3 was 13.9 per 1,000 person-years (95% CI, 13.3 to 14.5 per 1,000 person-years). The crude incidence rate after visit 3 of diabetes was 17.3 per 1,000 person-years (95% CI, 16.6 to 18.1 per 1,000 person-years).

There were no statistically significant associations between change in diet score and CVD risk based on HEI-2015, but only except for a slightly higher risk in the largest score increase group compared to the stable group by AHEI-2010 (HR, 1.22; 95% CI, 1.02 to 1.47) (**Supplemental Table 4**). There was also no statistically significant association between change in diet quality and diabetes risk (**Supplemental Table 5)**. We observed an association between a large decrease in AHEI-2010 score and incident diabetes after adjusting for demographic characteristics, socio-economic factors, family history of disease, lifestyle factors, and initial diet quality score in Model 1, but the association was attenuated and no longer statistically significant after accounting for change in other health behaviors in Model 2 and further adjustment for confounders in Model 3 and 4.

Compared to the participants with consistently low HEI-2015 scores over the six-year change period, participants who had decreased from the highest to the lowest tertile had a 67% higher risk of incident diabetes (HR, 1.67; 95% CI, 1.06 to 2.64) compared to the consistently low diet quality group in the fully adjusted model (**Supplemental Table 6**). No significant associations were observed for the 9 categories of HEI-2015 score change and CVD risk, as well as the 9 categories of AHEI-2010 score change and both CVD and diabetes risk with adjusted models.

Subgroup Analyses

The inverse association between diet quality score at visit 1 and incident CVD risk was consistent across subgroups by sex (p for interaction=0.80), race (p for interaction=0.64), education level (p for interaction=0.73), and BMI categories (p for interaction=0.17) using HEI-2015. There was a significant interaction by race for the association between AHEI-2010 diet quality score and incident CVD (p for interaction=0.004), with significant association among whites rather than African-Americans, but not for any other factors (**Supplemental Figure 1**).

DISCUSSION

In the present study, higher initial diet score was associated with a significantly lower risk of incident CVD, but not significantly associated with incident diabetes within a community-based population of middle-aged black and white men and women. This relationship was consistent across population subgroups, including sex, race, education level, and BMI category. Diet quality slightly improved over a six-year period between the late 1980's and the 1990s, but there was no consistent and significant association between change in diet quality and risk of incident CVD or incident diabetes in the overall study population.

Our findings are partially consistent with previous research. In line with existing epidemiology studies using the earlier version of HEI and AHEI-2010 measurements, there was a strong association between the higher single measurement of diet quality and the reduced CVD risk for both the HEI-2015 and AHEI-2010 (8–12). Although HEI and AHEI diet scores were developed for slightly different purposes, they both capture essential elements of high-quality diet (17), with commonality in desirable food groups, such as fruits, vegetables, whole grains, and unsaturated fats, as well as potentially detrimental food groups or ingredients, such as high intake of sodium. Both these two diet quality indices strongly predict CVD risk in ARIC Study population. However, HEI-2015 presented a stronger and more consistent dose-response relationship with CVD risk than AHEI-2010, especially for the secondary outcomes of heart failure and stroke. The possible interpretation might be the fact that HEI-2015 and AHEI-2010 vary in different components and optimal cutoffs. Compared with AHEI-2010, HEI-2015 has a separate component for protein from seafood and plant. Seafood and plant protein was significantly associated with a lower risk of CVD comparing to other sources of protein food (32). But in AHEI-2010, there was no information related to seafood protein. The stronger association between HEI-2015 and CVD might be driven separately accounting for different food sources of protein.

Previous analyses based the Nurses' Health Study (NHS) and the Health Professionals Follow-up Study (HPFS) had concluded that HEI-2005 and AHEI-2010 were strongly associated with diabetes risk (12). However, we did not observe such significant association between HEI-2015 and AHEI-2010 score and diabetes risk in the ARIC Study population. But our findings are consistent with previous analysis of HEI-2010 and diabetes risk in the Multiethnic Cohort (13). The results might suggest that HEI-2015 and AHEI-2010 have limited benefit in preventing diabetes for a more generalized population.

Few studies have previously investigated the association between change in HEI-2015 score and CVD or diabetes risk. Deterioration in diet quality as assessed using AHEI-2010 was associated with higher risk of CVD and diabetes in the NHS and the

HPFS population (17,18). However, we were not able to replicate these findings for AHEI-2010 in the present study. The inconsistency in these findings might be due to differences between the diet measurements, study populations, and incidence rates. Diet information was collected with 66-item FFQ in ARIC, while with 131-item FFQ in NHS and HPFS. The more detailed FFQ in items might be more likely to detect diet quality change than our present study. In contrast with the participants in the NHS and HPFS who are relatively homogenous with respect to demographic and socioeconomic status (mostly white and well-educated health professionals), ARIC Study participants were enrolled from four distinct U.S. regions representing both blacks and whites, both men and women, and a relatively wide range of socioeconomic status as indicated by education level. The mean age of ARIC population was also nearly 4 years older than the age used for analyses in NHS and HPFS. The overall incidence rate of CVD in the NHS and HPFS pooled study population was around 9 per 1,000 person-years, which was lower than 13 per 1,000 person-years in the present study. The incidence rate of diabetes was also much lower in the NHS and HPFS pooled study population than in our study (5 vs. 17 per 1,000 person-years, respectively). Lifestyle factors, including diet quality and other important health behaviors, as well as the general health status among the health professionals were better than among ARIC Study participants. Also, in the Cox models in the present analyses, we additionally adjusted for eGFR, which is an important predictor for CVD (33), and was not adjusted in the NHS and HPFS studies, to better control for confounders.

It is well established that high BMI is a major determinant of CVD (34–36). Our study showed that high diet quality was associated with a lower CVD risk among overweight participants, but not for participants with normal weight or obesity, although there was no statistical evidence of interaction. Nonetheless, this may imply that conducting diet intervention might benefit overweight people most to reduce their CVD risk, which was consistent with the findings from a Meta-analysis that dietary intervention had strong effects on reducing predicted CVD risk among overweight and obese adults (37).

Our study has several strengths. We conducted the present study in a community-based population of black and white adults in the U.S., providing broader generalizability relative to previous research on this topic. To provide a comprehensive analysis of diet quality and cardiometabolic diseases, we included several important outcomes including overall CVD, diabetes, and secondary outcome of heart failure, coronary heart disease, stroke. Due to repeated assessment of dietary intake, we were able to quantify the change in diet quality whereas prior studies have predominantly used a single measure of diet quality. We used two measures of diet quality, including the latest version of the HEI-2015 to assess adherence to the Dietary Guidelines for Americans as well as the AHEI-2010 which assesses relevant aspects of the diet for chronic disease prevention. The study participants in our sample were followed for an extended period of time to allow for the ascertainment of many incident CVD and diabetes cases.

The limitations of this study also deserve consideration. Self-reported dietary intake by food frequency questionnaire is prone to recall bias and other types of error (38). Also, the 66-item FFQ may not have captured the while diet. Another limitation is that the sample size in some sub-groups was small, which reduces the statistical power to detect significant associations. Finally, although we adjusted for many potential confounders and accounted for change in the covariates, we are not able to rule out the influence of residual and unmeasured confounding in this observational study.

CONCLUSIONS

In summary, we observed strong associations between higher diet quality, assessed using HEI-2015 and AHEI-2010, with lower CVD risk in a community-based population of middle-aged black and white men and women. There was a slight improvement in diet quality over a six-year period between the late 1980's and the 1990s. We did not observe significant and consistent associations between change in diet quality and CVD or diabetes risk. Our results provide scientific evidence that adherence to dietary guidelines may protect against CVD and confer benefits for CVD prevention within the general U.S. population. Further research might focus on determining the possible effect of longer-term diet quality change on disease risk in large cohort populations.

APPENDICES

Main Tables

Table 1: Baseline (Visit 1, 1987-1989) Characteristics of Participants by Quintiles of Initial Diet Quality Score

	HEI-2015				AHEI-2010			
	Q1	Q3	Q5	P-value	Q1	Q3	Q5	P-value
Participants, n	2216	2216	2215		2216	2216	2215	
Diet Score, mean (SD)	58.2 (4.4)	70.6 (1.2)	82.5 (3.6)	<0.001	62.7 (7.0)	70.5 (6.8)	78.4 (6.8)	<0.001
Energy intake, mean (SD), kcal/day	1765.0 (677.8)	1653.2 (591.9)	1459.0 (495.7)	<0.001	1709.1 (626.2)	1591.7 (618.2)	1644.3 (551.2)	<0.001
Age, mean (SD), years	53.1 (5.6)	53.7 (5.7)	54.5 (5.7)	<0.001	53.0 (5.6)	53.7 (5.7)	54.3 (5.7)	<0.001
Female, No. (%)	903 (40.7)	1278 (57.7)	1524 (68.8)	<0.001	985 (44.4)	1231 (55.6)	1441 (65.1)	<0.001
Black, No. (%)	534 (24.1)	608 (27.4)	390 (17.6)	<0.001	593 (26.8)	573 (25.9)	338 (15.3)	<0.001
Education level, No. (%)								
< high school	665 (30.0)	449 (20.3)	264 (11.9)	<0.001	564 (25.5)	478 (21.6)	275 (12.4)	<0.001
≥ high school	1552 (70.0)	1767 (79.7)	1951 (88.1)		1652 (74.6)	1738 (78.4)	1940 (87.6)	
Smoking Status, No. (%)								
current smoker	822 (37.1)	531 (24.0)	356 (16.1)	<0.001	688 (31.0)	574 (25.9)	436 (19.7)	<0.001
former smoker	684 (30.9)	646 (29.2)	785 (35.4)		635 (28.7)	661 (29.8)	834 (37.7)	
never smoker	710 (32.0)	1039 (46.9)	1074 (48.5)		893 (40.3)	981 (44.3)	945 (42.7)	
Physical activity index, mean (SD)	2.3 (0.7)	2.4 (0.8)	2.7 (0.8)	<0.001	2.3 (0.8)	2.5 (0.8)	2.7 (0.8)	<0.001
Alcohol intake, mean (SD), drinks/day	0.6 (1.3)	0.4 (1.0)	0.3 (0.6)	<0.001	0.5 (1.3)	0.5 (0.9)	0.5 (0.8)	<0.001
Weight, mean (SD), lb.	173.6 (36.0)	170.4 (35.4)	162.9 (33.5)	<0.001	174.5 (36.1)	170.2 (35.6)	165.5 (34.3)	<0.001
BMI, mean (SD), kg/m^2	27.1 (5.0)	27.3 (5.0)	26.6 (4.9)	<0.001	27.4 (5.2)	27.2 (5.1)	26.8 (4.8)	<0.001
BMI level, No. (%)								
< 25 kg/m^2	814 (36.7)	742 (33.5)	965 (43.6)	<0.001	779 (35.2)	794 (35.8)	846 (38.2)	0.005
≥ 25, <30 kg/m^2	853 (38.5)	936 (42.2)	815 (36.8)		890 (40.2)	894 (40.3)	915 (41.3)	
≥ 30 kg/m^2	549 (24.8)	538 (24.3)	435 (19.6)		547 (24.7)	528 (23.8)	454 (20.5)	
Hypertension, No. (%)	628 (28.3)	714 (32.2)	663 (29.9)	0.014	670 (30.2)	699 (31.5)	623 (28.1)	0.021
Hypercholesterolemia, No. (%)	511 (23.1)	544 (24.5)	593 (26.8)	0.022	516 (23.3)	570 (25.7)	603 (27.2)	<0.001

eGFR, mean (SD), mL/min/1.73 m^2	103.0 (14.6)	103.2 (14.9)	102.1 (13.4)	0.035	103.3 (15.1)	103.3 (15.1)	101.6 (13.2)	<0.001
Family history of diabetes, No. (%)	499 (25.4)	476 (23.7)	472 (23.0)	0.30	484 (24.2)	516 (25.4)	471 (23.0)	0.53
Family history of CHD/stroke, No. (%)	1221 (62.0)	1241 (62.4)	1284 (63.0)	0.047	1204 (60.8)	1218 (60.4)	1276 (63.3)	0.24

Table 2: Risk of Incident Cardiovascular Disease by Quintiles of Initial Diet Quality Score (Visit 1, 1987-1989)

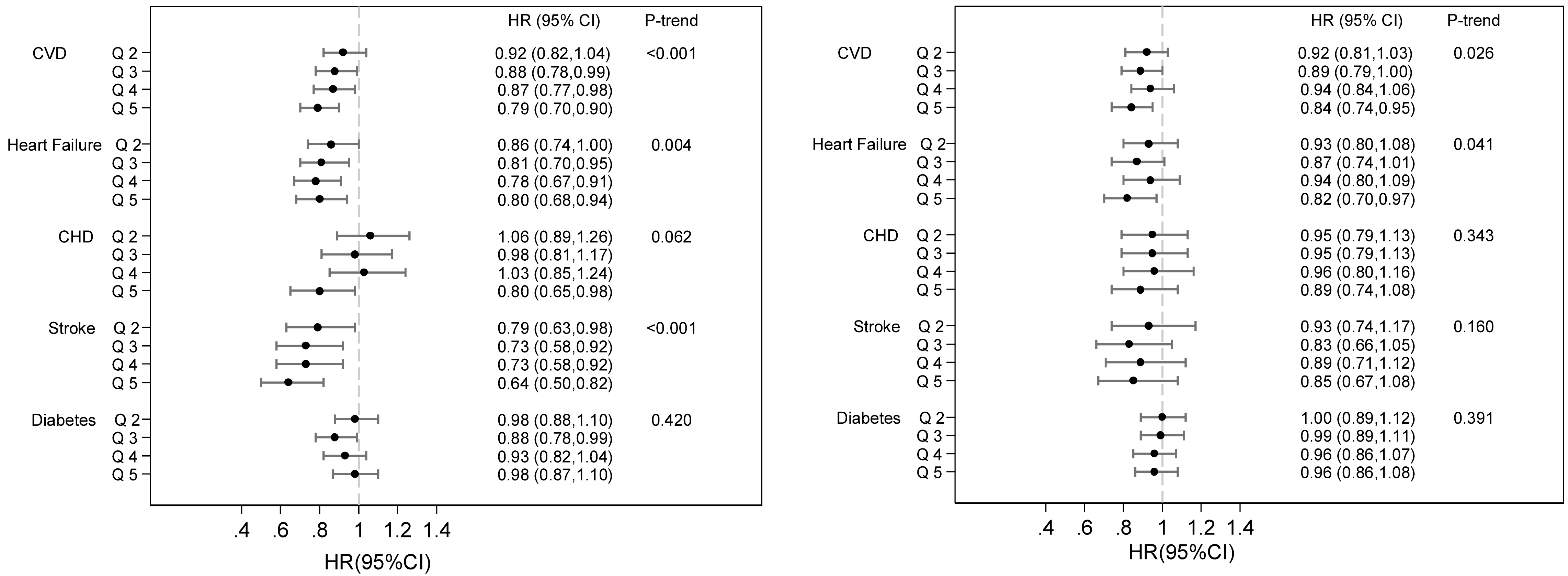
	Quintile 1 (N=2216)	Quintile 2 (N=2216)	Quintile 3 (N=2216)	Quintile 4 (N=2216)	Quintile 5 (N=2215)	P-trend[1]	HR per 10% increase
HEI-2015							
Cases/person-years	728/44591	634/46219	630/47592	615/48638	531/49634		
Incidence rate/1,000 person-year	16.33 (15.18-17.56)	13.72 (12.69-14.83)	13.24 (12.24-14.31)	12.64 (11.68-13.68)	10.70 (9.83-11.65)		
Crude HR	1 (ref.)	0.82 (0.74-0.92)	0.79 (0.71-0.88)	0.75 (0.68-0.84)	0.64 (0.57-0.71)	<0.001	0.84 (0.81-0.87)
Model 1	1 (ref.)	0.93 (0.83-1.05)	0.91 (0.81-1.03)	0.92 (0.81-1.04)	0.82 (0.72-0.93)	0.005	0.92 (0.88-0.96)
Model 2	1 (ref.)	0.92 (0.82-1.04)	0.89 (0.79-1.00)	0.88 (0.78-0.99)	0.79 (0.69-0.89)	<0.001	0.90 (0.86-0.95)
Model 3	1 (ref.)	0.92 (0.82-1.04)	0.88 (0.78-0.99)	0.87 (0.77-0.98)	0.79 (0.70-0.90)	<0.001	0.90 (0.86-0.95)
AHEI-2010							
Cases/person-years	686/45929	648/46583	622/47053	625/47977	557/49132		
Incidence rate/1,000 person-year	14.94 (13.86-16.10)	13.91 (12.88-15.02)	13.22 (12.22-14.30)	13.03 (12.04-14.09)	11.34 (10.43-12.32)		
Crude HR	1 (ref.)	0.92 (0.83-1.02)	0.87 (0.78-0.98)	0.86 (0.77-0.96)	0.74 (0.66-0.83)	<0.001	0.92 (0.89-0.95)
Model 1	1 (ref.)	0.92 (0.82-1.04)	0.91 (0.81-1.02)	0.96 (0.85-1.08)	0.85 (0.75-0.96)	0.051	0.96 (0.93-0.99)
Model 2	1 (ref.)	0.92 (0.82-1.04)	0.89 (0.79-1.01)	0.94 (0.84-1.06)	0.85 (0.75-0.96)	0.032	0.96 (0.93-0.99)
Model 3	1 (ref.)	0.92 (0.81-1.03)	0.89 (0.79-1.00)	0.94 (0.84-1.06)	0.84 (0.74-0.95)	0.026	0.96 (0.93-0.99)

Model 1 [visit 1 covariates]: age, race, education, family history of diabetes, family history of CHD/stroke, smoking status, physical activity, alcohol intake (only for HEI), total energy intake (all in quintiles)
Model 2: Model 1 + hypertension status, hypercholesterolemia status, eGFR (quintiles)
Model 3: Model 2 + BMI category
[1]Trend was tested using an ordinal variable for quintile of diet quality score.

Figure

Figure 1: Risk[1] of Incident Cardiovascular Disease and Incident Diabetes According to Quintile of Initial Diet Quality Score for HEI-2015 (A) and AHEI-2010(B)

(A) HEI-2015 **(B) AHEI-2010**



[1] Hazard ratios calculated using quintile 1 as reference group, adjusted for age, sex, race, education, family history of diabetes, family history of CHD/stroke, smoking status, physical activity, alcohol intake (only for HEI), total energy intake, hypertension status, hypercholesterolemia status, eGFR, and BMI category (Model 3).

Supplement Tables

Supplemental Table 1: HEI-2015[1] Scores and Changes from Visit 1 to Visit 3

Component	Score, mean (SD)		Absolute change	Relative change	P-value
	Visit 1	Visit 3	mean (SD)	mean (SD)	
Total	71.02 (8.66)	72.88 (8.44)	1.86 (7.72)	0.03 (0.12)	<0.001
Total Fruits[2]	4.42 (1.24)	4.53 (1.13)	0.11 (1.22)	0.20 (1.18)	<0.001
Whole Fruits[3]	4.37 (1.30)	4.54 (1.13)	0.17 (1.26)	0.18 (0.95)	<0.001
Total Vegetables[4]	2.43 (1.27)	2.64 (1.32)	0.21 (1.32)	0.33 (1.41)	<0.001
Greens and Beans[4]	4.41 (1.10)	4.47 (1.05)	0.06 (1.11)	0.10 (0.67)	<0.001
Whole Grains	3.84 (3.19)	3.79 (3.16)	-0.05 (3.30)	0.69 (3.04)	0.2
Dairy[5]	5.32 (3.20)	5.31 (3.23)	-0.01 (3.17)	0.64 (3.72)	0.8
Total Protein Foods[6]	4.84 (0.50)	4.81 (0.55)	-0.03 (0.61)	0.01 (0.20)	<0.001
Seafood and Plant Proteins[6,7]	4.55 (0.97)	4.46 (1.07)	-0.09 (1.12)	0.04 (0.53)	<0.001
Fatty Acids[8]	2.46 (2.07)	2.99 (2.19)	0.54 (2.47)	1.99 (30.20)	<0.001
Refined Grains	9.70 (1.16)	9.71 (1.14)	0.02 (1.43)	0.04 (0.67)	0.3
Sodium	9.76 (0.76)	9.74 (0.81)	-0.02 (0.99)	0.01 (0.24)	0.1
Added Sugars	9.92 (0.64)	9.98 (0.40)	0.06 (0.75)	0.01 (0.18)	<0.001
Saturated Fats	5.01 (3.04)	5.89 (3.04)	0.88 (3.21)	1.35 (21.84)	<0.001

[1]Intakes between the minimum and maximum standards are scored proportionately.

[2]Includes 100% fruit juice.
[3]Includes all forms except juice.
[4]Includes legumes (beans and peas).
[5]Includes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages.
[6]Includes legumes (beans and peas).
[7]Includes seafood, nuts, seeds, soy products (other than beverages), and legumes (beans and peas).
[8]Ratio of poly- and monounsaturated fatty acids (PUFAs and MUFAs) to saturated fatty acids (SFAs).

Supplemental Table 2: AHEI-2010 Scores and Changes from Visit 1 to Visit 3

Component	Score, mean (SD)		Absolute change	Relative change	P-value
	Visit 1	Visit 3	mean (SD)	mean (SD)	
Total	50.66 (12.09)	52.37 (11.31)	1.71 (11.32)	0.07 (0.26)	<0.001
Vegetables	2.87 (1.82)	3.12 (2.05)	0.25 (2.00)	0.37 (1.46)	<0.001
Fruit	3.52 (2.56)	4.01 (2.72)	0.49 (2.60)	0.75 (2.53)	<0.001
Whole grains	3.28 (3.01)	3.22 (2.99)	-0.06 (3.16)	0.73 (3.11)	0.1
Sugar-sweetened beverages & fruit juice	3.22 (3.80)	3.30 (3.84)	0.08 (3.86)	0.58 (10.16)	0.1
Nuts and legumes	5.36 (3.30)	5.37 (3.30)	0.01 (3.43)	0.37 (1.46)	0.8
Red/processed meat	6.61 (4.32)	7.24 (4.06)	0.63 (4.54)	1.33 (10.58)	<0.001
trans fat, % of energy	6.83 (1.86)	8.13 (1.65)	1.30 (1.92)	0.36 (2.20)	<0.001
Long-chain (n-3) fats (EPA +DHA)	6.32 (3.43)	6.75 (3.26)	0.43 (3.31)	0.25 (0.92)	<0.001
PUFA, % of energy	3.80 (1.75)	3.49 (1.65)	-0.31 (1.96)	0.38 (18.86)	<0.001
Sodium	4.82 (2.80)	3.87 (2.26)	-0.95 (3.29)	2.72 (57.43)	<0.001
Alcohol	4.01 (3.05)	3.85 (2.94)	-0.16 (3.15)	0.15 (1.12)	<0.001

Supplemental Table 3: Visit 3 (1993-1995) Characteristics of Participants by Categories of 6-Year Percent Changes in Diet Quality Scores

	Decrease		No Change or Stable (±3%)	Increase		P-value
	Large (>10%)	Small to Moderate (3-10%)		Small to Moderate (3-10%)	Large (>10%)	
HEI-2015						
Participants, n	805	1379	1733	1806	1880	
Diet Score at visit 1, mean (SD)	76.0 (8.4)	74.9 (7.8)	73.0 (7.9)	70.5 (7.2)	64.7 (7.4)	<0.001
Diet Score at visit 3, mean (SD)	64.5 (8.1)	70.3 (7.4)	73.1 (7.9)	74.9 (7.6)	76.2 (7.6)	<0.001
Absolute change in HEI score	-11.6 (4.1)	-4.6 (1.6)	0.0 (1.2)	4.4 (1.4)	11.6 (4.2)	<0.001
Energy intake change, mean (SD), kcal/day	107.6 (565.8)	34.6 (539.2)	19.2 (528.4)	-49.5 (533.9)	-123.1 (566.2)	<0.001
Age, mean (SD), years	59.9 (5.6)	59.8 (5.7)	59.5 (5.6)	59.4 (5.6)	59.0 (5.5)	<0.001
Female, No. (%)	477 (59.3)	787 (57.1)	1044 (60.2)	1067 (59.1)	1045 (55.6)	0.042
Black, No. (%)	143 (17.8)	233 (16.9)	327 (18.9)	319 (17.7)	389 (20.7)	0.048
Education level, No. (%)						
< high school	163 (20.2)	217 (15.7)	246 (14.2)	280 (15.5)	344 (18.3)	<0.001
≥ high school	642 (79.8)	1162 (84.3)	1487 (85.8)	1526 (84.5)	1536 (81.7)	
Smoking Status, No. (%)						
current smoker	158 (19.6)	255 (18.5)	250 (14.4)	281 (15.6)	294 (15.6)	0.023
former smoker	317 (39.4)	537 (38.9)	712 (41.1)	731 (40.5)	776 (41.3)	
never smoker	330 (41.0)	587 (42.6)	771 (44.5)	794 (44.0)	810 (43.1)	
Physical activity index, mean (SD)	2.4 (0.8)	2.5 (0.8)	2.6 (0.8)	2.6 (0.8)	2.6 (0.8)	<0.001
Alcohol intake, mean (SD), drinks/day,	0.4 (1.0)	0.5 (1.2)	0.4 (1.0)	0.4 (0.9)	0.4 (1.2)	0.26
Weight, mean (SD), lb.	175.5 (36.3)	172.0 (35.8)	171.2 (36.4)	172.3 (36.7)	172.7 (36.0)	0.088
Weight change, mean (SD), lb.	7.4 (12.7)	5.9 (11.6)	5.9 (11.3)	5.6 (12.0)	4.5 (11.8)	<0.001
BMI, mean (SD), kg/m^2	28.5 (5.2)	27.7 (4.9)	27.6 (5.2)	27.8 (5.3)	27.7 (5.1)	0.003
BMI change, mean (SD), kg/m^2	1.4 (2.1)	1.2 (1.9)	1.1 (1.8)	1.1 (2.0)	0.9 (1.9)	<0.001
BMI level, No. (%)						
< 25 kg/m^2	224 (27.8)	421 (30.5)	580 (33.5)	586 (32.4)	574 (30.5)	0.001
≥25, <30 kg/m^2	315 (39.1)	575 (41.7)	688 (39.7)	689 (38.2)	812 (43.2)	
≥ 30 kg/m^2	266 (33.0)	383 (27.8)	465 (26.8)	531 (29.4)	494 (26.3)	
Hypertension, No. (%)	312 (38.8)	527 (38.2)	651 (37.6)	678 (37.5)	678 (36.1)	0.65
Hypercholesterolemia, No. (%)	199 (24.7)	312 (22.6)	397 (22.9)	397 (22.0)	441 (23.5)	0.6

eGFR, mean (SD), mL/min/1.73 m^2	102.6 (12.8)	101.2 (13.9)	103.0 (13.6)	102.1 (13.9)	103.0 (13.8)	0.001
Family history of diabetes, No. (%)	180 (24.3)	280 (22.3)	354 (22.0)	384 (23.2)	393 (22.9)	0.75
Family history of CHD/stroke, No. (%)	457 (61.1)	787 (62.8)	979 (62.0)	1027 (62.1)	1051 (61.4)	0.94
AHEI-2010						
Participants, n	2022	888	793	893	3007	
Diet Score at visit 1, mean (SD)	57.6 (11.4)	55.9 (10.7)	53.2 (10.4)	50.8 (10.3)	43.7 (9.8)	<0.001
Diet Score at visit 3, mean (SD)	45.4 (10.1)	52.3 (10.0)	53.2 (10.3)	54.1 (11.0)	56.3 (10.6)	<0.001
Absolute changes in HEI score	-12.2 (6.0)	-3.6 (1.4)	-0.0 (0.9)	3.3 (1.2)	12.6 (6.3)	<0.001
Energy intake change, mean (SD), kcal/day	-64.1 (546.9)	-52.2 (500.7)	-14.9 (508.7)	8.0 (540.3)	9.2 (576.7)	<0.001
Age, mean (SD), years	59.4 (5.6)	59.7 (5.6)	59.9 (5.5)	59.5 (5.9)	59.3 (5.5)	0.041
Female, No. (%)	1193 (59.0)	523 (58.9)	472 (59.5)	533 (59.7)	1699 (56.5)	0.23
Black, No. (%)	339 (16.8)	137 (15.4)	160 (20.2)	147 (16.5)	628 (20.9)	<0.001
Education level, No. (%)						
< high school	335 (16.6)	128 (14.4)	137 (17.3)	138 (15.4)	512 (17.0)	0.35
≥ high school	1687 (83.4)	760 (85.6)	656 (87.2)	755 (84.6)	2495 (83.0)	
Smoking Status, No. (%)						
current smoker	349 (17.3)	145 (16.3)	125 (15.8)	132 (14.8)	487 (16.2)	0.73
former smoker	820 (40.6)	368 (41.4)	330 (41.6)	363 (40.6)	1192 (39.6)	
never smoker	853 (42.2)	375 (42.2)	338 (42.6)	398 (44.6)	1328 (44.2)	
Physical activity index, mean (SD)	2.5 (0.8)	2.6 (0.8)	2.6 (0.8)	2.6 (0.8)	2.5 (0.8)	0.006
Weight, mean (SD), lb.	174.2 (36.6)	170.6 (36.6)	170.4 (36.7)	170.0 (36.9)	173.1 (35.7)	0.006
Weight change, mean (SD), lb.	6.8 (12.4)	6.3 (11.0)	4.9 (11.3)	5.7 (11.4)	4.9 (11.9)	<0.001
BMI, mean (SD), kg/m2	28.2 (5.1)	27.6 (5.2)	27.4 (5.1)	27.5 (5.2)	27.8 (5.1)	<0.001
BMI change, mean (SD), kg/m^2	1.3 (2.0)	1.2 (1.8)	1.0 (1.8)	1.1 (1.9)	1.0 (1.9)	<0.001
BMI level, No. (%)						
< 25 kg/m^2	584 (28.9)	287 (32.3)	274 (34.6)	310 (34.7)	930 (30.9)	<0.001
≥ 25, <30 kg/m^2	801 (39.6)	376 (42.3)	321 (40.5)	352 (39.4)	1229 (40.9)	
≥ 30 kg/m^2	637 (31.5)	225 (25.3)	198 (25.0)	231 (25.9)	848 (28.2)	
Hypertension, No. (%)	798 (39.5)	332 (37.4)	284 (35.8)	333 (37.3)	1099 (36.5)	0.24
Hypercholesterolemia, No. (%)	482 (23.8)	196 (22.1)	174 (21.9)	202 (22.6)	692 (23.0)	0.77
eGFR, mean (SD), mL/min/1.73 m^2	101.9 (13.3)	102.2 (13.1)	102.8 (13.6)	102.5 (13.3)	102.6 (14.3)	0.34
Family history of diabetes, No. (%)	437 (23.7)	163 (20.2)	171 (23.3)	198 (23.6)	622 (22.6)	0.36

Family history of CHD/stroke, No. (%)	1136 (62.0)	481 (59.5)	448 (62.0)	517 (62.4)	1719 (62.4)	0.65

Supplemental Table 4: Hazard Ratios for Cardiovascular Disease by Categories of 6-Year Percent Changes in Diet Quality Scores

	Decrease		No change or Stable (±3%)	Increase	
	Large (>10%)	Small to Moderate (3-10%)		Small to Moderate (3-10%)	Large (>10%)
HEI-2015					
Participants, n	805	1379	1733	1806	1880
Cases/person-years	204/13895	326/23949	417/30664	411/32197	476/33419
Incidence rate/1,000 person-year	15.01 (13.08-17.21)	13.71 (12.30-15.28)	13.83 (12.56-15.22)	12.94 (11.75-14.25)	14.49 (13.24-15.85)
Crude Model	1.11 (0.94-1.31)	1.00 (0.87-1.16)	1 (ref.)	0.92 (0.80-1.06)	1.03 (0.90-1.17)
Model 1	1.04 (0.87-1.25)	0.93 (0.80-1.09)	1 (ref.)	0.90 (0.78-1.05)	0.97 (0.83-1.13)
Model 2	1.04 (0.86-1.24)	0.93 (0.79-1.09)	1 (ref.)	0.90 (0.77-1.04)	0.98 (0.84-1.14)
Model 3	1.05 (0.87-1.25)	0.94 (0.80-1.10)	1 (ref.)	0.91 (0.78-1.06)	0.98 (0.984-1.15)
Model 4	1.03 (0.86-1.24)	0.94 (0.80-1.10)	1 (ref.)	0.90 (0.78-1.05)	0.98 (0.84-1.14)
AHEI-2010					
Participants, n	2022	888	793	893	3007
Cases/person-years	478/35047	192/15630	187/13804	206/15556	771/52043
Incidence rate/1,000 person-year	13.61 (12.44-14.89)	12.28 (10.66-14.15)	13.55 (11.74-15.63)	13.24 (11.55-15.18)	14.81 (13.81-15.90)
Crude Model	1.01 (0.85-1.19)	0.90 (0.74-1.10)	1 (ref.)	0.97 (0.80-1.18)	1.09 (0.93-1.28)
Model 1	1.15 (0.95-1.38)	0.99 (0.80-1.24)	1 (ref.)	1.11 (0.89-1.37)	1.19 (1.00-1.43)
Model 2	1.15 (0.95-1.38)	1.03 (0.83-1.29)	1 (ref.)	1.13 (0.91-1.40)	1.23 (1.02-1.47)
Model 3	1.12 (0.93-1.35)	1.03 (0.82-1.28)	1 (ref.)	1.12 (0.90-1.39)	1.22 (1.02-1.47)
Model 4	1.11 (0.92-1.34)	1.04 (0.83-1.30)	1 (ref.)	1.13 (0.91-1.40)	1.22 (1.02-1.47)

Model 1 [visit 3 covariates]: age, sex, race, education, family history of diabetes, family history of CHD/stroke, smoking status, physical activity, alcohol intake (only for HEI), total energy intake, initial diet quality score (all in quintiles)
Model 2: Model 1 + change in smoking status (categorical), change in physical activity, change in alcohol intake (only for HEI), change in total energy intake (all in quintiles)
Model 3: Model 2 + hypertension status, hypercholesterolemia status, eGFR (quintiles)
Model 4: Model 3 + BMI category, change in BMI (quintiles)

Supplemental Table 5: Hazard Ratios for Diabetes by Categories of 6-Year Percent Changes in Diet Quality Scores

	Decrease		No change or Stable (±3%)	Increase	
	Large (>10%)	Small to Moderate (3-10%)		Small to Moderate (3-10%)	Large (>10%)
HEI-2015					
Participants, n	805	1379	1733	1806	1880
Cases/person-years	237/12298	366/21069	453/27191	452/28569	535/29080
Incidence rate/1,000 person-year)	19.3 (17.0-21.9)	17.37 (15.7-19.3)	16.7 (15.2-18.3)	15.8 (14.4-17.4)	18.4 (16.9-20.0)
Crude Model	1.17 (1.00-1.37)	1.05 (0.92-1.21)	1 (ref.)	0.95 (0.83-1.08)	1.11 (0.98-1.26)
Model 1	1.10 (0.93-1.30)	1.06 (0.92-1.23)	1 (ref.)	0.91 (0.79-1.04)	0.99 (0.86-1.14)
Model 2	1.09 (0.92-1.30)	1.06 (0.91-1.23)	1 (ref.)	0.91 (0.79-1.06)	0.98 (0.84-1.13)
Model 3	1.09 (0.92-1.29)	1.06 (0.91-1.23)	1 (ref.)	0.91 (0.79-1.05)	0.98 (0.85-1.14)
Model 4	1.04 (0.88-1.23)	1.03 (0.89-1.20)	1 (ref.)	0.90 (0.78-1.04)	1.00 (0.86-1.16)
AHEI-2010					
Participants, n	2022	888	793	893	3007
Cases/person-years	568/31174	224/14079	190/12475	217/13878	844/46602
Incidence rate/1,000 person-year	18.2 (16.8-19.8)	15.9 (14.0-18.1)	15.2 (13.2-17.6)	15.6 (13.7-17.9)	18.1 (16.9-19.4)
Crude Model	1.20 (1.02-1.41)	1.04 (0.86-1.26)	1 (ref.)	1.03 (0.85-1.25)	1.19 (1.01-1.39)
Model 1	1.21 (1.01-1.45)	1.14 (0.92-1.40)	1 (ref.)	1.04 (0.84-1.28)	1.14 (0.96-1.36)
Model 2	1.19 (1.00-1.43)	1.12 (0.91-1.39)	1 (ref.)	1.03 (0.84-1.28)	1.12 (0.94-1.33)
Model 3	1.16 (0.97-1.39)	1.10 (0.89-1.36)	1 (ref.)	1.02 (0.83-1.26)	1.11 (0.94-1.33)
Model 4	1.11 (0.93-1.33)	1.08 (0.88-1.33)	1 (ref.)	1.02 (0.82-1.26)	1.11 (0.93-1.32)

Model 1 [visit 3 covariates]: age, sex, race, education, family history of diabetes, family history of CHD/stroke, smoking status, physical activity, alcohol intake (only for HEI), total energy intake, initial diet quality score (all in quintiles)
Model 2: Model 1 + change in smoking status (categorical), change in physical activity, change in alcohol intake (only for HEI), change in total energy intake (all in quintiles)
Model 3: Model 2 + hypertension status, hypercholesterolemia status, eGFR (quintiles)
Model 4: Model 3 + BMI category, change in BMI (quintiles)

Supplemental Table 6: Hazard Ratios for Cardiovascular Disease and Diabetes by 9 Diet Quality Score Change Groups

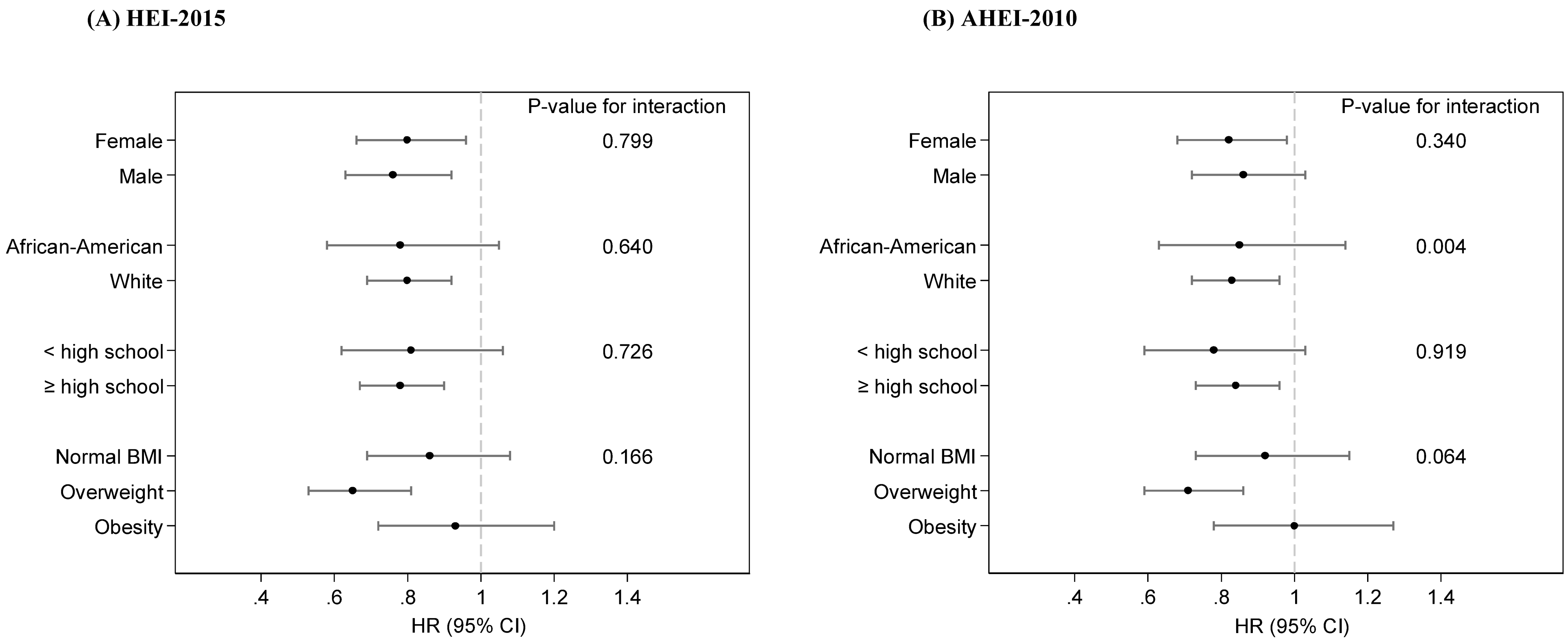
Group (Visit 1- Visit 3)	N	Visit 1 Score Mean (SD)	Visit 3 Score Mean (SD)	Crude HR for CVD	Adjusted HR[1] for CVD	Crude HR for Diabetes	Adjusted HR[1] for Diabetes
HEI-2015							
Low-Low	1286	60.2 (5.3)	60.9 (5.0)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Low-Medium	847	62.6 (4.1)	70.9 (2.2)	0.84 (0.71-1.00)	0.97 (0.80-1.17)	0.94 (0.80-1.11)	1.01 (0.84-1.21)
Low-High	402	63.4 (4.0)	78.9 (3.1)	0.80 (0.64-1.00)	1.00 (0.78-1.29)	0.93 (0.75-1.14)	1.05 (0.83-1.33)
Medium-Low	476	70.8 (2.1)	63.2 (4.0)	0.97 (0.79-1.19)	1.02 (0.75-1.38)	0.85 (0.70-1.04)	0.98 (0.74-1.30)
Medium-Medium	1027	71.1 (2.1)	71.5 (2.1)	0.76 (0.64-0.90)	0.86 (0.65-1.14)	0.79 (0.67-0.92)	0.93 (0.72-1.19)
Medium-High	1031	71.5 (2.1)	79.6 (3.5)	0.79 (0.67-0.92)	0.94 (0.70-1.25)	0.76 (0.65-0.89)	1.01 (0.77-1.33)
High-Low	130	79.2 (3.6)	63.8 (3.9)	0.78 (0.54-1.15)	1.01 (0.59-1.71)	1.26 (0.94-1.71)	1.67 (1.06-2.64)
High-Medium	618	79.0 (3.3)	71.9 (2.1)	0.85 (0.70-1.03)	0.96 (0.65-1.40)	0.88 (0.73-1.06)	1.35 (0.94-1.94)
High-High	1786	80.9 (4.3)	81.6 (4.2)	0.71 (0.62-0.82)	0.94 (0.65-1.36)	0.74 (0.64-0.85)	1.21 (0.85-1.72)
AHEI-2010							
Low-Low	1218	36.3 (6.0)	37.6 (5.4)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Low-Medium	906	38.4 (5.1)	49.8 (2.9)	0.95 (0.80-1.12)	0.99 (0.82-1.19)	0.94 (0.80-1.11)	1.00 (0.83-1.19)
Low-High	411	40.0 (4.2)	61.1 (4.6)	0.98 (0.78-1.22)	0.98 (0.76-1.25)	0.99 (0.80-1.22)	0.97 (0.77-1.22)
Medium-Low	572	49.6 (3.0)	39.5 (4.3)	0.83 (0.68-1.02)	0.76 (0.56-1.04)	0.93 (0.77-1.12)	1.04 (0.78-1.37)
Medium-Medium	1016	50.2 (3.0)	50.3 (3.0)	0.79 (0.66-0.94)	0.76 (0.57-1.02)	0.85 (0.72-0.99)	1.03 (0.79-1.34)
Medium-High	946	50.5 (3.0)	62.1 (5.3)	0.91 (0.77-1.08)	0.82 (0.61-1.10)	0.96 (0.82-1.13)	1.19 (0.91-1.56)
High-Low	196	60.9 (4.7)	39.6 (4.4)	1.06 (0.79-1.42)	0.83 (0.53-1.32)	1.09 (0.83-1.43)	1.14 (0.75-1.74)

High-Medium	729	62.4 (5.8)	51.0 (3.0)	0.91 (0.76-1.10)	0.83 (0.57-1.22)	1.01 (0.85-1.20)	1.32 (0.93-1.88)
High-High	1609	65.3 (7.2)	65.1 (6.9)	0.86 (0.74-1.00)	0.81 (0.56-1.17)	0.75 (0.65-0.86)	1.08 (0.77-1.53)

[1]Adjusted for age, sex, race, education, family history of diabetes, family history of CHD/stroke, smoking status, physical activity, alcohol intake (only for HEI), total energy intake, initial diet quality score (all in quintiles), change in smoking status (categorical), change in physical activity, change in alcohol intake, change in total energy intake (all in quintiles), hypertension status, hypercholesterolemia status, eGFR (quintiles), BMI category, change in BMI (quintiles)

Supplement Figure

Supplemental Figure 1: Risk[1] of Cardiovascular Disease for High (Quintile 5) vs. Low (Quintile 1) Diet Quality Score According to Sex, Race, Education Level, and BMI category for HEI-2015 (A) and AHEI-2010 (B)



[1] Hazard ratios were presented for the low (quintile 1) versus high (quintile 5) diet score, adjusted for age, sex, race, education, family history of diabetes, family history of CHD/stroke, smoking status, physical activity, alcohol intake (only for HEI), total energy intake, hypertension status, hypercholesterolemia status, eGFR, and BMI category.

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CURRICULUM VITAE

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PROFILE

Master of Science candidate in Epidemiology with a strong research interest in diabetes and cardiovascular disease prevention. Research assistant with experience in observational and intervention studies in both the U.S. and China. Interdisciplinary background in Medicine, Sociology, and Epidemiology. Clinical internship experience in hospital in China. Community volunteer serving in a variety of health education programs.

EDUCATION

Master of Science (ScM) in Epidemiology (Current GPA: 3.92/4.00) Expected May 2018

Johns Hopkins Bloomberg School of Public Health, Baltimore, MD

Thesis: Diet quality, Change in diet quality and risk of incident cardiovascular disease and diabetes: The Atherosclerosis Risk in Communities (ARIC) Study

Advisors: Dr. Casey M. Rebholz & Dr. Elizabeth Selvin

Bachelor of Medicine (BM) in Preventive Medicine (graduation with honors) Jul. 2016

Bachelor of Laws (LLB) in Sociology Overall GPA: 3.77/4.00 (Top 5%)

Peking University, Beijing, China

Undergraduate Global Learning Semester program in Global Health Fall 2015

Duke Kunshan University, Kunshan, China

Relevant Coursework: Fundamentals of Global Health, Social Determinants of Health, Biostatistics and Epidemiology

ABSTRACTS

- **Xu Z**, Steffen LM, Selvin E, Rebholz CM. Change in Diet Quality and Risk of Incident Diabetes: The Atherosclerosis Risk in Communities Study. *Circulation,* 2018;137: AP213 http://circ.ahajournals.org/content/137/Suppl_1/AP213
- Lin HB, Zhang DD, Shen P, **Xu Z**, Si YQ, Tang X, Gao P. Multimorbidity and Risk of Mortality in China: Results from the Chinese Electronic Health Records Research in Yinzhou (CHERRY) Study. *Circulation,* 2017;135: AP166 http://circ.ahajournals.org/content/135/Suppl_1/AP166

PUBLICATIONS

- Xu YF, **Xu Z**, Shi W, et al. Network communication-based intervention in dietary practices among college students. *Chinese Journal of School Health*, 2015 (12), 1814-1817. http://en.cnki.com.cn/Article_en/CJFDTOTAL-XIWS201512021.htm
- **Xu Z**, Wang LL. Participatory health education effect on HIV/AIDS prevention among high school seniors in Zezhou county, Shanxi province. *Chinese Journal of Reproductive Health*, 2015 (01), 74-77.

RESEARCH EXPERIENCE

Master Thesis Mar. 2017 - Present

Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD

Project title: Change in Diet Quality and Risk of Incident Diabetes: The Atherosclerosis Risk in Communities (ARIC) Study

Advisors: Dr. Casey M. Rebholz & Dr. Elizabeth Selvin

- Developed the proposal for the thesis project of six-year diet change and subsequent diabetes risk using ARIC Study
- Performed survival analysis on diet quality assessment based on Healthy Eating Index and association

with diabetes risk in Cox regression models; Conducted sensitivity analysis using different models and subgroup populations.
- Developed write a first-author manuscript

Research Assistant Feb. 2018 - Present

Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD
Project title: Cholesterol intake and source among U.S. adults: NHANES 2013-2014
Supervisors: Dr. Lawrence J. Appel
- Conducted data analyses to describe the cholesterol intake distribution based on NHANES data
- Write a first-author manuscript (in progress)

Research Assistant Jun. 2017 – Jan.2018

Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD
Project title: Systematic Review of Dietary Phosphorus Intake and Blood Pressure
Supervisors: Dr. Lawrence J. Appel & PhD Candidate Scott McClure
- Conducted title/abstract screening, full text screening, and data extraction for a systematic review on research of dietary phosphorus intake and blood pressure in adults
- Assisted with lecture preparation on feeding studies and their impact on nutrition policy

Undergraduate Thesis Oct. 2015 - Jun. 2016

Peking University, School of Public Health, Beijing, China
Project title: The Chinese Electronic Health Records Research in Yinzhou (CHERRY) Study
Supervisors: Dr. Pei Gao & Dr. Xun Tang
- Conducted data cleaning/management on electronic health records from multiple sources
- Performed descriptive analysis of multi-morbidity and mortality risk among over 900,000 Chinese population
- Developed bachelor's degree thesis entitled: Prevalence of Cardio-metabolic Multi-morbidity and Mortality: Preliminary Results from the Chinese Electronic Health Records Research in Yinzhou (CHERRY) Study

Research Assistant May 2013 - Jun. 2014

Peking University, *School of Public Health Beijing, China*
Project title: Network communication-based intervention in dietary practices among college students
Supervisor: Dr. Wenli Zhu
- Designed questionnaire and multilevel sampling for the study of the text-message intervention on nutrition improvement among undergraduates in Beijing, China
- Conducted pre-post analysis to evaluate the effects of the intervention
- Developed a paper as the second-author published in the Chinese Journal of School Health in 2015

Research Assistant Apr. 2013 - Aug.2013

Peking University, School of Public Health, Beijing, China
Project title: Evaluation the effects of health education on HIV/AIDS prevention among students
Supervisor: Dr. Linlin Wang
- Developed the protocol and questionnaire for the interventional study of health education on HIV/AIDS prevention among college students in Shanxi, China
- Conducted data collection, data management, and analysis for evaluating the effects of participatory health education on HIV/AIDs prevention
- Developed a paper as the first-author published in the *Chinese Journal of Reproductive Health* in 2015

TEACHING EXPERIENCE

Teaching Assistant Jan. 2018 - Mar.2018

Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD
Instructors: Dr. David Dowdy and Dr. Keri Althoff

Course: 340.753.01 Epidemiologic Methods 3 (5 Credits)

- Developed course materials in conjunction with instructors, drafted exam questions and graded exams

INTERNSHIP EXPERIENCE

Clinical Intern Mar. 2014 - Jan. 2015

Beijing Shijitan Hospital & 302 Military Hospital of China, Beijing, China

- Completed rotation in departments of Internal Medicine, General Surgery, and Infectious Diseases
- Assisted doctors in chronic diseases in-patients care and medical records management

Field Work Intern Jul. 2015 - Aug. 2015

Center for Disease Control and Prevention (CDC) of Fangshan District, Beijing, China

- Participated in the field investigations on environmental health and community health education activities
- Conducted data analysis to describe the prevalence of Metabolic Syndrome among 8595 residents in China

HEALTH EDUCATION/COMMUNITY SERVICE EXPERIENCE

Project Advisor May 2014- Jun.2016

Peking University, Department of the Communist Youth League, Beijing, China

- Administered education materials and posters to promote the health habits of primary school students in Tibet
- Organized the delivery of prescribed medicine to local children regularly under the guidance of pediatrician

Vice Minister Aug. 2012- Aug. 2013

Peking University, Publicity Department of Institute Student Union, Beijing, China

- Designed posters and handbooks on the preventive knowledge of HIV/AIDS for "World AIDS Day" promotion activities among migrants and students
- Implemented HIV/AIDS prevention activities for migrants /students at railway station and universities in Beijing, China

HONORS, AWARDS AND SCHOLARSHIPS

China Scholarship Council (CSC) Full scholarship for Master program in the U.S. 2016 - 2018
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Master's Tuition Scholarship of Johns Hopkins Bloomberg School of Public Health 2017

Graduation with honors from Peking University (Top 5%) 2016

First-class Scholarship of Peking University (Top 5%) in every academic year 2011-2015

Merit Student of Peking University (Top 5%) in every academic year 2011-2015

Outstanding Individual for Community Service of Peking University 2013, 2012

COMPUTER SKILLS

Microsoft Access, SPSS, Stata, SAS, R, REDCap, ArcGIS